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BORDEN'S REVIEW *of* NUTRITION RESEARCH

Summaries and reviews of research information concerning the nutritive values of milk and milk products. Published by The Borden Company, 350 Madison Avenue, New York, N. Y.

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THE NUTRITIVE VALUE OF BUTTER

Although the production of milk in the United States during 1942 was the largest in history, the demand for dairy products has exceeded the supply to such an extent that the American civilian market is short of some of these products. Among them is butter. Recognition of the role which butter plays in good nutrition causes the government to provide the men in the armed forces with more than double the amount they ate as civilians. In addition, the armed forces are putting away reserves of butter to make sure they will have butter when and where needed.

Resulting shortages of butter for civilian use bring that essential fat into prominent attention before nutritionists and the public. Its wholesome appeal and distinctive flavor established butter as a favorite food many generations ago, a rank which it still holds today. Normally, butter provides more than one-third of the necessary fats in the American dietary.

Aside from its palatability and the richness of flavor and texture which it imparts to other foods in cooking, baking, or as a spread, scientific research has revealed that butter is a highly nutritious food. Butter is a concentrated source of energy. It contributes part of the necessary quota of fat, a major portion of the vitamin A requirement, and some of the vitamin D requirement. In addition to its vitamin content, butter provides significant amounts of certain dietary essentials known as fatty acids.

Within the past two years, evidence has been steadily growing that butter contains a factor capable of promoting superior growth. At present there are indications that this factor may be especially significant in the nutrition of infants and young children who are dependent, to a large degree, on milk as a major food in their diet. Because certain vegetable fats and oils have been found to be inferior to butter fat in growth-promoting properties, nutrition authorities have voiced the opinion that products in which butterfat has been partially or completely replaced by such vegetable fats cannot be considered equal in nutritive value to the original butter-containing foods.

Role of Fat in the Diet

Fats are the most concentrated source of energy and, weight for weight, supply more than twice the energy derived from either proteins or carbohydrates. In the average American diet fats constitute approximately one-fourth to one-third of the total caloric intake.

In addition to providing a source of immediate energy, fats constitute the most important form of stored energy in the body. Reserve depots of stored fat offer a source of energy which may be drawn upon in times of emergency when the food supply is limited.

Fats serve many other functions in addition to supplying calories. Fat stored in layers under the skin and around delicate internal organs acts as a heat insulator and shock absorber and serves the esthetic function of rounding out the sharp, angular contours of the body. Fats contribute to the so-called "staying-power" of a diet because they require a longer time for digestion than do either proteins or carbohydrates. For this reason they are of importance in delaying sensations of hunger. A diet low in fat is very likely to create an abnormal feeling of hunger a few hours after meals. Fats are essential in the structure and function of all tissues, especially of the brain and nerves. They are also necessary for the absorption and utilization of the fat-soluble vitamins. In addition, some fats are actually natural sources or carriers of these vitamins.

In the United States, the average total fat consumption is about 50 pounds per person each year, including the fat content of foods, such as meat, as well as all types of shortenings. Butter constitutes about 14 to 19 pounds of this amount, thus representing an appreciable fraction of the fat intake. In addition, it is interesting to note that of the fats ordinarily used as such in the daily diet, butter is the only one which is a *natural* carrier of the fat-soluble vitamins, contributing significant amounts of vitamin A as well as some vitamin D.

Butter—A Source of Vitamins A and D and Nutritionally Essential Fatty Acids

Butter is an excellent source of vitamin A. Recognition of this fact goes back to the early experiments of McCollum and Davis (1) and Osborne and Mendel (2) in 1913. These experimenters found that the ability of a synthetic diet of pure protein, fat, carbohydrate and mineral salts to support life in laboratory animals was determined by the nature of the fat used in the diet. They found that, with certain fats they could not obtain satisfactory growth or prolonged life on their synthetic diets, but that when butter was provided as

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the source of fat, normal growth ensued and life could be maintained. This led to the conclusion that something other than fats *per se* was essential in the diet, and further, that certain fats such as butter fat provide this additional nutritive factor. Further investigation led to the discovery of a new nutritional element. Coming at a time when knowledge about the importance of certain vital food constituents in trace quantities was just being crystallized, this new factor discovered in butter was named vitamin A.

Before the results of these epic-making nutritional studies in America became generally known, tragic confirmation of the human need for this vitamin was being demonstrated among the children of Denmark during the first World War (3).

For some years before, and especially during the war, hospitals in Denmark were filled with hundreds of children afflicted with the dread eye disease, xerophthalmia. During the first few years little was known about the cause or treatment for this disease with the result that progressive destruction of the eye tissues of afflicted children continued unchecked, ending in total blindness. Blindness was soon followed by severe respiratory infection and death. It took several years following the publication in 1913 of McCollum and Davis' and Osborne and Mendel's work for the mystery of xerophthalmia in Denmark to be cleared up. Before and during the war, Denmark, primarily a dairy-farming country, manufactured and exported butter in great quantities. During the war, the chief source of vitamin A for children—butter and whole milk products—was exported to foreign countries in greater amounts. As often said since: "The eyesight of the children was sold abroad with the butter."

In 1918 the German blockade prevented the export of butter and, as a result, butter was rationed in Denmark at a little more than one-half pound per person a week. Other fats were not available, so that everybody had to eat butter. Xerophthalmia ceased simultaneously. These facts showed as clearly as an experiment that the absence of the fat-soluble vitamin A normally provided by butter and whole milk products was the cause of xerophthalmia, blindness and death among the children of Denmark.

The Vitamin A Content of Butter: The vitamin A value of milk, and consequently butter and other milk products, in the past was subject to appreciable seasonal variations. Summer milk and butter produced when cows were on fresh pasture were usually richer in vitamin A content than winter milk or butter produced when cows were fed indoors on dry fodder. With increased knowledge concerning the nutrition and feeding of dairy cows, however, it is becom-

ing the practice among dairy farmers to feed vitamin-rich rations the entire year in order to secure maximum productivity. Such practice, at the same time, materially enhances the vitamin value of milk, so that there is no longer a sharp distinction in vitamin A values between winter and summer milk.

Wilson (4) reports appreciable increases in milk production, for example, following feeding of a vitamin A and D concentrate, and in addition, increased fat content of the milk and higher vitamin A potency. Hauge (5) likewise has reported that with proper rations including carotene-rich alfalfa, clover and silages, the vitamin A value of butter can be considerably increased. Deuel and co-workers (6) have been able to obtain butter fat of extremely high vitamin A content from cows fed large doses of vitamin A as supplements to the regular feed. The situation is summed up by Sherman and Lanford (7) as follows:

> **"While sub-normal levels of vitamins A, B (B_1), and C in milk have all been produced experimentally, the rations used to induce them are such as are known, if long used, to diminish the productivity of the cow, so that dairy farmers have no desire to use them. Hence in practice few cows are so fed, and those that are do not yield enough milk to have much influence on the quality of the market supply. The modern farmer feeds his milch-cows vitamin-rich rations the year round. Thus milks of subnormal vitamin A, B, or C value are less common in the market, and commercial winter milk is more like summer milk, than the scientific literature might lead one to expect."**

The vitamin A value of butter is 3500 to 5000 international units per 100 grams. During the past ten years the average annual per capita consumption of butter has been slightly over 17 pounds. Hence butter provides 15 to 20 per cent of the recommended allowance of 5000 I. U. of vitamin A per day for adults.

The Vitamin D Content of Butter: Vitamin D, popularly known as the "sunshine vitamin" because the precursor is activated by the ultra-violet rays of the sun, is the one vitamin which does not occur to any appreciable extent in most foods. Aside from fish liver oils, which are not commonly considered part of the ordinary diet, vitamin D occurs naturally in only a few foods such as fish of high fat content (salmon, herring, mackerel, sardines), egg yolk and butter. The butter fat in milk naturally contributes the vitamin D of milk. Irradiation methods considerably enhance the vitamin D content of milk. Other irradiated foods also contribute to the available supply of vitamin D. Butter, containing most of the vitamin D of milk, has been estimated (8) to contain from about 50 to 500 I. U. of vitamin D per pound, depending again upon the feed of the cow and seasonal variations. Butter is thus a fair source of vitamin D, a generous intake supplying as much as one-sixth of the daily requirement of 400 I. U.

Essential Fatty Acids: About fourteen years ago a series of new nutritionally essential factors was postulated by Burr and Burr (9, 10). These nutrients were characterized chemically as fatty acids of a highly unsaturated type and were later identified as linoleic and linolenic acids.

The reactive *unsaturated* fatty acids are capable of taking up additional hydrogen. The saturated fatty acids contain all the hydrogen they are capable of holding. *Unsaturated* acids can be converted to the saturated form by the process known as *hydrogenation*. This process is used commercially to convert vegetable oils such as cottonseed oil to a solid form, in the preparation of many common household shortenings.

Burr and Burr found that if linoleic and linolenic acids are not provided in the diet, animals fail to grow and soon develop a characteristic deficiency disease. Symptoms of this disease include the development of a scaly skin dermatosis, kidney damage, hematuria (blood in urine) and are eventually followed by death. It was later found by Turpeinen (11) that still another unsaturated fatty acid, arachidonic acid, was even more potent in correcting the deficiency than the other two acids. Other workers have advanced the belief that linoleic and linolenic acids are precursors of arachidonic acid and that the latter is the physiologically active compound. This belief is based in part upon experimental work showing that arachidonic acid is deposited in the liver after feeding the other two acids (12). The biological experiments indicating that animals apparently cannot synthesize linoleic, linolenic and arachidonic acids have received confirmation through recent studies with isotopes or "labeled" atoms*.

The role of the unsaturated fatty acids in human nutrition is at present still being investigated. There remains no doubt, however, that a nutritionally adequate diet should provide a source of these factors. Most fats, including both animal and vegetable, are good sources of linoleic, linolenic and arachidonic acids.

A great deal of research is being conducted to determine the exact quantitative, as well as qualitative, nature of the fatty acids in butter. Present knowledge indicates that butter is a very adequate source of the essential fatty acids. Hilditch *et al* (14) have estimated butter to contain from 1.9 to 3.7 per cent of linoleic acid; these figures have also been confirmed by Burr (15). Eckstein (16) has reported values of 0.07 to 0.17 per cent linolenic acid in butter, but stated that due to limitations of the analytical method, these values are probably lower than the true values. He noted futher that the linolenic acid content

*For description of the isotope technique see Borden's Review of Nutrition Research, Vol. III, No. 1, October, 1942.

of butter may be appreciably increased by the incorporation of linseed meal in the feed of the cow. Bosworth and Brown (17) report the presence in butter of significant quantities of acids of the arachidonic type, as have a number of other investigators.

Butterfat Promotes Superior Growth

A little more than four years ago a group of scientists conducting animal nutrition experiments at the University of Wisconsin, noticed that young animals grew somewhat faster and appeared to have a better coat of hair when fed butter than when fed vegetable fats such as corn oil and coconut oil (18). This was indeed surprising because, with the early recognition of butter as a source of vitamin A, all experimental diets not containing butter or other food sources of the vitamin were supplemented as a routine matter with crystalline carotene (provitamin A) or a vitamin A concentrate, in addition to all the other known vitamins. The question was thus raised as to the reason, other than vitamin A, for the difference in growth on butter fat and vegetable fat diets. These observations and the question which they posed led to a series of new investigations designed to discover what component of butter was responsible for this difference.

Preliminary results of these investigations were published by Schantz, Elvehjem and Hart (19) two years later, in 1940. They found that various skim milk samples fortified with iron, copper and manganese, and to which different fats had been added all produced good growth, but that mineralized skim milk with added corn oil, coconut oil, cottonseed oil or soybean oil in place of the natural butter fat did not stimulate as good growth, especially during the early weeks of life. The animals fed butter fat also had a better appearance and superior coats of hair. After considerable investigation, these workers were able to demonstrate that the growth-promoting activity was not in the non-saponifiable fraction of butter fat. (i.e., the fraction containing oil-soluble materials which are not true fats). Further studies were therefore concentrated on the saponifiable (true fat) portion of butter fat.

A first possibility appeared to be that the difference in the nutritive value of butter fat and the vegetable oils might be due to some particular phospholipid in the butter fat which was not in the vegetable fats. Accordingly, tests were conducted in which a common phospholipid, egg lecithin, was added to the vegetable oils in amounts calculated to render the phospholipid content of these oils equivalent to that of butter (20). Results showed that egg lecithin improved the nutritive value of corn oil and coconut oil slightly, but not enough to give growth equal to that obtained on butter fat. Other phospholipids had no effect at all in

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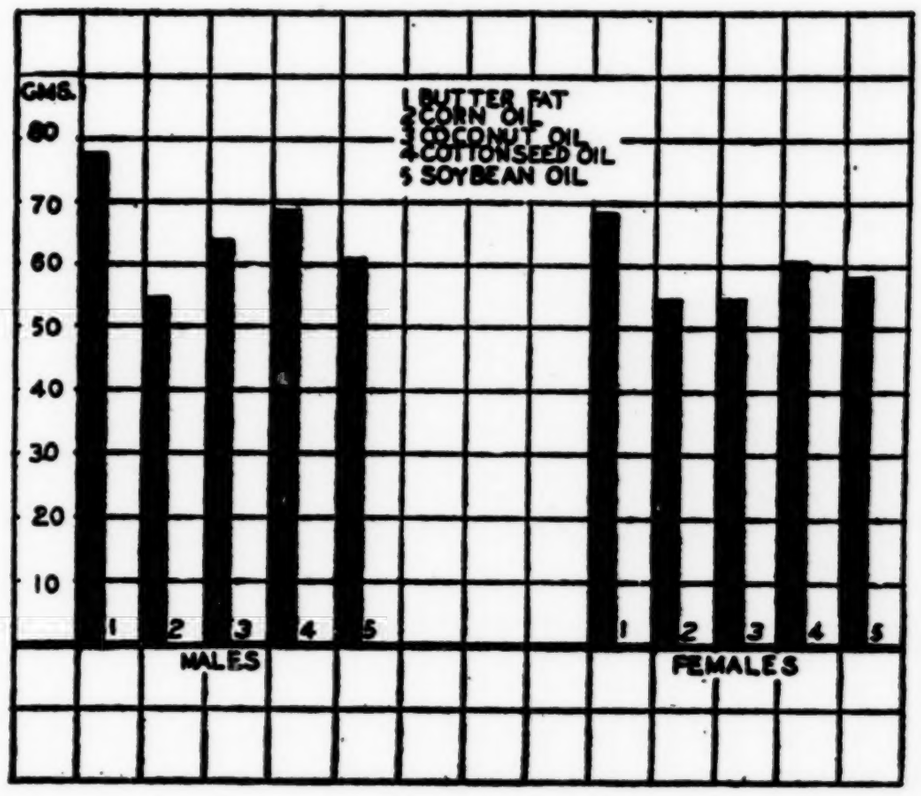
CHART 1



*Average gain made during the first three weeks of experiment by male and female rats representing 6 rats (3 males, 3 females) on each of the following fats: butter fat, corn oil, coconut oil, cottonseed oil, and soybean oil.

altering the nutritive value of the vegetable oils. The additional fact that soybean oil was found to be inferior to butter fat irrespective of its high phospholipid content (20), offered further indication that the superior growth obtained with butter is due to something in the saponifiable fraction other than a phospholipid.

These observations narrowed down the search for the growth-stimulating factor to the fatty acids contained in butter. Accordingly, the fatty acids were separated into three parts: the volatile acids, the non-volatile saturated acids, and the non-volatile unsaturated acids. Each of these fractions was incorporated separately into a vegetable oil and the three samples compared as to growth-promoting effects. It was found that the vegetable oil containing the *saturated* fatty acid fraction of the butterfat was the one which effectively promoted superior growth (21). It was concluded that the growth-stimulating activity was caused by one or more of the *saturated* fatty acids in butter.

The possibility existed that the activity of the *saturated* fraction might be due to the presence of an unsaturated acid still remaining as an impurity. Accordingly, this fraction was subjected to hydrogenation to remove any such impurity. The completely hydrogenated fraction (i.e., completely saturated) gave even better growth. These observations confirmed the conclusion that the unidentified factor in butter is a *saturated* fatty acid (or acids).

It is interesting to note that some of the unsaturated acids in butter may be converted to the active *saturated* factor by hydrogenation. Experiments with

vegetable oils indicate, however, that the unsaturated acids in these fats are of a different type and that when these are subjected to hydrogenation, they do not yield saturated acids of the same type or nutritive value as the butter factor (22).

More recently, Gullickson, Fountaine and Fitch (23) conducted very similar experiments with young calves and also reported superior nutritive value for butter fat as contrasted with lard, corn oil, cottonseed oil, soybean oil, tallow, coconut oil, and peanut oil. Freeman and Ivy (24) likewise working along these lines have also found butter fat to possess somewhat superior growth-stimulating properties.

Conclusion:

In view of research findings in the studies of the nutritional values of butter, it is not surprising to find that the United States Bureau of Home Economics gives butter an individual classification in its recent simple grouping of all foods into twelve nutritional classifications. This grouping of foods permits the practical application of the principles of good nutrition by the entire population without any special individual knowledge of nutrition. The choice each day of one or more foods from each of the following food groups will insure a complete and well-balanced diet:

(1) Milk and milk products; (2) potatoes and sweet potatoes; (3) dry mature beans, peas and nuts; (4) tomatoes and citrus fruits; (5) leafy green and yellow vegetables; (6) other vegetables and fruits; (7) eggs; (8) lean meat, poultry and fish; (9) flours and cereals; (10) butter; (11) other fats; (12) sugars.

The designation of butter as an item distinct from other dairy products and from other fats is indicative of its high nutritional value. Butter contributes to the fat quota and to the essential unsaturated fatty acid requirement. Butter is distinctive in its natural vitamin content. It apparently also contains an essential nutritive factor which has not been found in vegetable oils.

Before the discovery of the vitamins, it was recognized that milk as a whole was superior in nutritive value to any mixture containing all the known constituents of milk. Likewise, it would seem probable that, with factors still being discovered in butter fat, butter as a whole is nutritively superior to any mixture of its known constituents.

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NEWS DIGEST

THE INDISPENSABILITY OF CERTAIN AMINO ACIDS for laboratory animals has been recognized for some time. The first conclusive evidence that some of these amino acids are indispensable for man as well, has recently been announced. Two male adults served as subjects for nitrogen balance studies designed to determine the protein adequacy of the diet. On a carefully controlled diet containing all the nutritional essentials, the subjects maintained normal nitrogen equilibrium. When either the amino acid *methionine* or *valine* was removed from the diet, the subjects both responded immediately with a negative nitrogen balance despite the fact that the protein content of the diet was maintained at the same level by the addition of other amino acids. Administration of *methionine* or of *valine* immediately effected a restoration of normal nitrogen balance. These observations indicate that both *methionine* and *valine* are indispensable dietary components for man. It is expected that studies of the remaining eight amino acids, classified as "indispensable" for animals, will soon clarify their role in human nutrition.

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YEAST when boiled affords nearly three times as much thiamin as does fresh yeast. This conclusion was reached as a result of urinary excretion studies on six human subjects which revealed that more than twice the amount of thiamin is excreted after feeding boiled yeast than after feeding fresh yeast. It is believed that boiling, by facilitating the digestion of yeast, increases the assimilability of thiamin from the yeast. Results of a similar nature, although not as marked, indicated increased utilization of riboflavin also from yeast which has been boiled.

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RESISTANCE TO INFECTION is closely associated with the nutritional state of the body. Investigators have found that deficiency of the B vitamins especially increases the susceptibility of monkeys to spontaneous respiratory infections. In the case of experimentally introduced diseases, the nutritionally deficient animals had considerably lower resistance to the disease than did well-nourished animals inoculated with the same disease viruses. The decreased resistance was further accompanied by a higher mortality rate.

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POWDERED LIVER has now been added to the list of dehydrated meats. A new method has made possible the reduction of liver to a fine brown powder which can be preserved indefinitely without refrigeration and which takes up only about one-fifth of its original space. Hitherto it has been possible to send liver abroad, or even to the domestic market, only by keeping it continuously frozen. Now it is reduced to a liquid by treating it with papain (a protein-hydrolyzing enzyme); the water is removed by means of a vacuum spray dryer and the resultant product is the desired powder. The water may be restored if desired, or the powder may be mixed with other materials for cooking.

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VITAMIN C is retained for a longer time in root crops such as carrots, turnips, potatoes, and large vegetables like cabbage, squash and pumpkin. Leafy vegetables, on the other hand, lose their vitamin C rapidly if kept at room temperature. The vitamin C of peas and lima beans is retained well while in the pod, but is lost rapidly after shelling. Generally, vegetables retain their vitamin C content best when held at a temperature just about freezing.

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MAR 18

DEHYDRATED CARROT JUICE COCKTAIL, wrapped in moisture-proof, air-tight cellophane envelopes, is now being marketed in place of a similar liquid product formerly sold in cans. The ingredients of the cocktail mix include dehydrated carrot powder, mint, salt, and dehydrated celery. A pocket-sized envelope of the cocktail mix is said to make a quart and a half of carrot juice cocktail which may be served either hot or cold.

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VITAMIN P, one of the newer vitamins whose existence has long been questioned, has recently been isolated from lemon peel. The vitamin is partly protein in nature and functions as an oxidation-reduction enzyme. The physiological functions of vitamin P are to prevent localized hemorrhage by regulating capillary permeability, decreasing capillary fragility and influencing blood pressure. Vitamin P is also known as *citrin* and as far as is known at present, is found only in lemon peel.

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NICOTINIC ACID (NIACIN), one of the B vitamins, has recently been used with considerable success in the treatment of angina pectoris. The vitamin was injected intravenously in a series of treatments and elicited beneficial results of a remarkably uniform and lasting nature. The action of niacin was consistent in most of the cases, effectively reducing blood pressure and heart rate.

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FRESH CARROTS fed to laboratory animals as the sole ingredient in the diet over a period of ten days, have been found to afford marked protection against the lethal effects of exposure to high altitudes. Under the experimental conditions, the animals were placed in a decompression chamber simulating an altitude of 30,000 ft. for two hours. Eighty percent of the carrot-fed animals survived the exposure to "high altitude" whereas only twenty percent of the control animals survived. Experiments are now in progress to determine the factors responsible for the protective effect of the carrot diet. Although this work is only in the earliest stages of development, it is conceivable that further studies may yield information of tremendous significance in the problems of high altitude flying.

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